AL.2.2002-89
c.2
v.3

ALBERTA SOIL AND WATER QUALITY GUIDELINES FOR HYDROCARBONS AT UPSTREAM OIL AND GAS FACILITIES

VOLUME 3: USER GUIDE

September 2001

DRAFT

Alberta
Environment

Pub. No: T/622
ISBN: 0-7785-1897-3 Printed Edition
ISBN: 0-7785-1900-7 On-line Edition
Web Site: http://www.gov.ab.ca/env/

Any comments, questions, or suggestions regarding the content of this document may be directed to:

Land Branch
Science and Standards Division
Alberta Environment
4th Floor, Oxbridge Place
9820 – 106th Street
Edmonton, Alberta T5K 2J6
Phone: (780) 427-5883
Fax: (780) 422-4192

or by e-mail to : Ted.Nason@gov.ab.ca

DRAFT

Additional copies of this document may be obtained by contacting:

Information Centre
Alberta Environment
Main Floor, Great West Life Building
9920 – 108th Street
Edmonton, Alberta T5K 2M4
Phone: (780) 944-0313
Fax: (780) 427-4407
Email: env.infocent@gov.ab.ca

September 2001

TABLE OF CONTENTS

1. INTRODUCTION 1
   - 1.1 Background 1
   - 1.2 Regulatory Context 1
   - 1.3 Case Studies 3
2. GUIDELINE DECISION PROCESS 3
   - 2.1 Decision on Closure Type 3
     - 2.1.1 Type A - Unconditional Closure 3
     - 2.1.2 Type B - Unconditional Closure (On-Site Management) 4
     - 2.1.3 Type C - Conditional Closure 4
   - 2.2 Decision on Guideline Tier 4
     - 2.2.1 Tier 1 (Generic) Guidelines 5
     - 2.2.2 Tier 2 (Modified Generic) Guidelines 5
     - 2.2.3 Tier 3 (Site-Specific Risk Assessment) 5
   - 2.3 Determination of Management Level 5
   - 2.4 Determination of Soil Type 6
   - 2.5 Determination of Land Use 6
   - 2.6 Selection of Applicable Exposure Pathways 7
   - 2.7 Selection of Chemicals of Concern 8
     - 2.7.1 Determining Whether PAH Analysis is Required 8
     - 2.7.2 Expressing PAHs as Equivalent B(a)P Concentration 10
   - 2.8 Subsoil Guidelines 10
3. SITE ASSESSMENT 10
   - 3.1 Sampling 10
   - 3.2 Analytical Requirements 11
4. USING TIER 1 GUIDELINES 11
   - 4.1 Soil 12
     - 4.1.1 Applicability of Tier 1 Guidelines 12
     - 4.1.2 Tier 1 Decision Tree 12
     - 4.1.3 Subsoil Guidelines 13
   - 4.2 Groundwater 13
   - 4.3 Regulatory Acceptance 14
5. USING TIER 2 GUIDELINES 14
   - 5.1 Tier 2A 15
     - 5.1.1 Introduction 15
     - 5.1.2 Tier 2A Adjustments 16
       - 5.1.2.1 Human Indoor Vapour Inhalation 16
       - 5.1.2.2 Protection of Potable Groundwater 17

DRAFT

5.1.2.3 Protection of Groundwater for Aquatic Life or Livestock Watering........18
5.1.2.4 Adjusting Hydrocarbon Composition........19
5.1.3 Tier 2A Groundwater Guidelines........19
5.1.4 Regulatory Acceptance........19
5.2 Tier 2B........19
5.2.1 Subsoil Guidelines........20
5.2.2 Ecological Soil Contact Pathway Suspended at Paved or Gravelled Sites........20
5.3 Tier 2C........20
5.3.1 Requirements........21
5.3.2 Regulatory Acceptance........22
6. SITE-SPECIFIC (TIER 3) REMEDIATION OBJECTIVES........22
7. REFERENCES........24

LIST OF TABLES

Table 1 Management Levels
Table 2 Relative Carcinogenic Potency Factors for PAH Compounds
Table 3 Alberta Tier 1 Hydrocarbon Guidelines for Fine Surface Soil
Table 4 Alberta Tier 1 Hydrocarbon Guidelines for Coarse Surface Soil
Table 5 Alberta Hydrocarbon Guidelines for Fine Subsoil
Table 6 Alberta Hydrocarbon Guidelines for Coarse Subsoil
Table 7 Alberta Hydrocarbon Guidelines for Groundwater

DRAFT

LIST OF FIGURES

Figure 1 Regulatory Process for Tier 1, Tier 2, and Tier 3 Guidelines
Figure 2 Decision Tree for Tier 1 Soil Guideline Selection

LIST OF CASE STUDIES (IN PREPARATION)

Case Study 1 Flare Pit
Case Study 2 Pipeline Break

1. INTRODUCTION

1.1 Background

The operation of upstream oil and gas facilities can result in the release of hydrocarbon compounds to the environment. This can be a concern either during the operation of the facility, or after decommissioning when land is returned to its former use. Site closure is a term often used to describe regulatory acceptance that decommissioning is complete, and the land is ready to revert to its former or a new use. The hydrocarbon soil and groundwater quality guidelines presented here were developed to assist in environmental management and site closure of upstream oil and gas facilities in Alberta.

This document is the final part of a three volume report on hydrocarbon soil and groundwater quality guidelines for the upstream oil and gas industry in Alberta. Volume 1 provided the protocol for guideline development. Volume 2 described in detail the guideline development process. This document (Volume 3) summarizes the guideline values and provides guidance on how the guidelines are to be used.

DRAFT

It should be noted that, in addition to hydrocarbons, there are a range of other chemicals that could be released from upstream oil and gas facilities, including salts, metals, and process chemicals. If these other chemicals are present at a site, they will require assessment and/or management. See *Salt Contamination Assessment and Remediation Guidelines* (AENV 2001a) and CCME (1999) for information on compounds not directly addressed in this guidance document.

1.2 Regulatory Context

Current Alberta Environment policy ("*A Proposed Management Framework for Reclamation and Remediation of Oil and Gas Exploration and Production Sites in Alberta*; AENV 2000a) defines and differentiates two groups of activities related to site closure:

- *Reclamation* refers to activities that restore the *surface* of the land to it's former capability (grade, ability to support crops, etc.).
- *Remediation* refers to activities that address issues of contaminant concentrations in soil, subsoil and groundwater at a site.

Successful reclamation is acknowledged by a reclamation certificate. Procedures for obtaining a reclamation certificate are documented elsewhere (*e.g.*, AENV, 1995) and are not repeated here. Closure conditions that are compatible with the issue of a reclamation certificate are highlighted in Table 1.

Successful remediation activity is currently acknowledged by AENV through the issue of letters of compliance only within municipal zoning systems. Letters of compliance are **not** presently issued against remedial activities at upstream oil and gas sites. However, three states of closure are defined here based on AENV (2000a): A) Unconditional Closure B) Unconditional Closure with acknowledgement that passive on-site management is included in the closure conditions for the site, and C) Conditional Closure, requiring off-site conditions to be addressed. These 3 closure states correspond to 3 different closure documents (Table 1). A fourth type of closure, "Deferred Closure" is defined in AENV (2000a), but is not discussed further in this document. One of the main functions of the guidelines developed by this project is to set standards for issuing letters of compliance.

Another recent regulatory document (AENV, 2000b) sets out current guidance for risk management at contaminated sites. Three options for risk management are provided (Figure 1), corresponding to the three Tiers of guidelines discussed in this document. Tier 1, or generic guidelines are numerical values that are protective of human and ecological health at a wide variety of sites throughout Alberta. Tier 2 is defined in AENV (2000b) as a modification of Tier 1 guidelines that may be developed by a proponent by replacing generic with site specific parameters in guideline calculations for certain pathways. Tier 3 refers to site-specific risk assessment and/or risk management.

DRAFT

Combining closure conditions and tiers defines the management level. Seven management levels are defined, of which four are presently applicable to upstream oil and gas sites. In the list below, entries that are greyed out are **not** presently available for management of upstream oil and gas sites:

Tier 1
Tier 2A
Tier 2B
Tier 2C
Tier 3A
Tier 3B
Tier 3C

Management to Tier 1 or Tier 2A (which are effectively equivalent) is the most desirable outcome. Occasionally, situations will arise where site-specific risk assessment/risk management is appropriate and/or necessary. Tier 3A entails site-specific assessment of all pathways considered at Tier 1 and management to the same environmental endpoints. Most often this will be based on adoption of Tier 1 human health guidelines and development of site-specific eco-contact objectives from a battery of bioassays. Tier 3C is on-going management of difficult sites based on site-specific assessment. Such sites are not eligible for the reclamation certification process. Tiers 2B, 2C, and 3B are not presently applicable to upstream oil and gas sites in Alberta.

Providing guidance on site-specific risk assessment is outside the scope of this document. This Volume includes sufficient information for users of Tier 1 guidelines. Proponents wishing to develop Tier 2 and Tier 3 guidelines will find useful information in all three volumes. Assistance with determining the appropriate guideline Tier to use is provided in Section 2.2.

Further discussion of closure conditions, tiers and management levels is provided in Section 2. Concepts introduced there are illustrated in Appendices 1 and 2.

1.3 Case Studies

Two Case Studies are provided in Appendices 1 and 2 to illustrate the processes described in this User Guide. Case Study 1 considers a flare pit at a wellsite, while Case Study 2 is based on a pipeline break.

2. GUIDELINE DECISION PROCESS

There are a number of decisions required in order to select or develop the appropriate set of guidelines for a particular site. Each of the following Sections highlights one of those decisions, and explains how that decision is made.

2.1 Decision on Closure Type

Three potential closure conditions for Upstream Oil and Gas Sites in Alberta are considered in this document. Type A closure is the desired outcome and the only type eligible for a reclamation certificate at present. Types B and C are presented as technical options for discussion. Management level 3C is accessible for on-going management of sites not eligible for a reclamation certificate

- Type A - Unconditional Closure;
- Type B - Unconditional Closure (On-Site Management); and,
- Type C - Conditional Closure.

All three closure conditions aim to provide the same level of protection to human health and the environment. Differences arise mainly in how, by whom, and over what period risks are managed (AENV, 2000a). The three closure conditions are described in more detail in the following Sections.

2.1.1 Type A - Unconditional Closure

Type A Closure implies that all normal activities that could occur under the land use designation are protected, (*i.e.,* land use is not restricted). Sites may be eligible for Unconditional Closure either i) by being "screened out" from further consideration after a rigorous Phase 1 assessment; ii) after analytical testing that shows compliance with the Unconditional Closure guidelines for soil and groundwater; or, iii) after remediation and confirmatory analyses that show compliance with the Unconditional Closure guidelines for soil and groundwater (AENV, 2000a). Unconditional Closure is the preferred option at any site where it is technically and economically feasible.

DRAFT

NB. Greyed out entries throughout the text are not presently available for management of upstream oil and gas sites.

2.1.2 Type B - Unconditional Closure (On-Site Management)

Type B closure could be used to acknowledge certain conditions at sites where on-site contamination exceeds Type A closure guidelines, but where exposure to human and ecological receptors does not exceed acceptable limits *under present conditions*. The purpose of Type B closure is to maintain a record of contaminant conditions at a site that might become important if plans for that site change (within the same land use) in the future.

2.1.3 Type C - Conditional Closure

DRAFT

Type C Closure is an option that may be available when technical or economic considerations make Types A or B Closure impractical. This option presently applies at Tier 3 only. Type C Closure is used where off-site contamination is present and institutional or engineered controls are required to restrict human or ecological exposure through one or more pathways. Type C Closure therefore allows certain guidelines to be relaxed while maintaining the same level of human and ecological protection as with Types A and B Closure. Landowner participation is a crucial element of a risk management plan involving Type C Closure. Sites managed to Type C closure at Tier 3 are not eligible for a Reclamation Certificate.

2.2 Decision on Guideline Tier

Current AENV policy on risk management at contaminated sites is provided in the document:

- *Policy for Management of Risks at Contaminated Sites in Alberta.* AENV (2000b).

Proponents should familiarize themselves with the framework laid out in this document. Three Options are provided in AENV (2000b). These three Options correspond to the three guideline Tiers used in this project. Figure 1 summarizes how the three Tiers of guidelines fit into the regulatory process from site assessment to regulatory acceptance. The three Tiers are as follows:

- Tier 1 or generic guidelines;
- Tier 2 or modified generic guidelines; and,
- Tier 3 or risk based site-specific remediation objectives.

The following three Sections provide more detail about the three Tiers, and guidance as to when each Tier is applicable.

2.2.1 Tier 1 (Generic) Guidelines

Generic guidelines are based on identification of the values (i.e., receptors) to be protected under each land use, the applicable exposure pathways and a corresponding set of parameters which allow reasonably conservative predictions of risk at sites throughout Alberta. Tier 1 guidelines are expected to be applicable to the majority of upstream oilfield sites in Alberta. There will, however, be a few sites where site conditions result in a *more* sensitive scenario than the conservative generic scenarios considered (*e.g.*, a site underlain by very coarse sand and gravels with a high hydraulic conductivity, see Section 4.1.1). In such cases, a Tier 2 or Tier 3 approach will be required. Even at sites that eventually use a Tier 2 or Tier 3 approach, Tier 1 guidelines are normally used for an initial screening as the first step in a phased site assessment. The use of Tier 1 guidelines is described in detail in Section 4.

2.2.2 Tier 2 (Modified Generic) Guidelines

There may be circumstances where, based on the conditions at a particular site, the generic guidelines are unnecessarily conservative. Accordingly, guidance is provided in Section 5 on ways in which the generic guidelines can be customized to a particular site, including a discussion of parameters that could have their generic values replaced by site-specific values. In general, a decision to proceed with a Tier 2 approach will be made by weighing the additional effort of collecting further site data and developing Tier 2 guidelines against possible savings in remedial effort.

DRAFT

2.2.3 Tier 3 (Site-Specific Risk Assessment)

Large or complex sites may require site-specific risk assessment, with or without toxicity testing, to develop appropriate remediation objectives. Regulatory guidance is available to assist with this process, and some information in all three Volumes of this project may be of use, but such work is outside the scope of the present document.

2.3 Determination of Management Level

The combination of closure type and guideline Tier is referred to as the "Management Level". Tiers 2 and 3 are subdivided into 3 Management Levels each, corresponding to the three closure types (A, B, and C). Tier 1 is not subdivided. As stated in Sections 1.2 and 2.1, only management level A is presently eligible for a Reclamation Certificate. The available Management Levels are summarized in Table 1.

2.4 Determination of Soil Type

Generic guidelines are available for two soil types, Coarse and Fine. These soils are defined as having a median grain size greater or less than 75 microns, respectively.

Selection of the appropriate set of guidelines is based on the soil type that controls contaminant migration at the site, based on professional judgement. For example, a continuous layer of Coarse soil beneath the water table will often govern groundwater flow in the saturated zone, even though its thickness may be small in relation to the total thickness of saturated Fine soils. In cases where it is not clear which soil type should be applied at a site, the more conservative guidelines for Coarse soil will be applied.

2.5 Determination of Land Use

Soil guidelines have been developed for five generic land uses – natural area, agriculture, residential/parkland, commercial and industrial. A generic land use scenario is envisioned for each category based on the "normal" activities on these lands. For most sites in Alberta, one of the five generic land use scenarios should be applicable. If none of the generic land uses are applicable, a Tier 3 approach will be required. The five land uses are defined as follows:

DRAFT

Natural Areas: are defined as being away from human habitation and activities, where the primary concern is the protection of ecological receptors. Accordingly, human soil ingestion, dermal contact and indoor air inhalation are not considered, as these pathways are not expected to be limiting in this land use. However, the protection of groundwater for drinking water pathway *is* included in this land use, based on the AENV definition (AENV, 2001b) of a domestic use aquifer (DUA), which applies in all land uses. Much of the "green area" (*i.e.*, the boreal forest) of Alberta, and wildlands in national or provincial parks will fall into natural area land use. *Lands within the Green Area that are specified as grazing leases represent an intergrade to Agricultural land use. On such grazing leases, the Soil Ingestion (Livestock) and Protection of Groundwater for Livestock pathways MUST be addressed.*

Agricultural Lands: the primary land use is growing crops or tending livestock. This also includes agricultural lands that provide habitat for resident and transitory wildlife and native flora. The portion of a farm that houses people is considered a residential land use. Based on an interpretation of guidance from the Alberta Energy and Utilities Board (EUB, 1996 and 1999), it is assumed that a setback of at least 15 m is present between an oilfield wellhead and any present or future residence.

Residential Land Use: is where the primary activity is residential or recreational activity. This land use includes urban parks, and campground areas, but not wildlands in national or provincial parks.

Commercial Land Use: the primary activity is commercial (*e.g.*, shopping mall) and there is free access to all members of the public, including children. The use may include, for example, commercial day-care centers. It does not include operations where food is grown. Commercial land use is not anticipated to be a frequent future use of upstream oil and gas facilities, but is included to retain completeness and compatibility with other documents, including CCME (2000a,b).

Industrial Land Use: the primary activity involves the production, manufacture or construction of goods. Public access is restricted and children are not permitted continuous access or occupancy.

2.6 Selection of Applicable Exposure Pathways

There are a wide range of exposure pathways by which chemicals of concern may reach human and ecological receptors. The pathways considered by this project are adapted from CCME (2000a) and are summarized below:

Human pathways

- soil ingestion;
- soil dermal contact;
- *indoor vapour inhalation; and,
- *protection of potable groundwater.

DRAFT

Ecological Pathways

- plant/invertebrate soil contact;
- soil ingestion by livestock or wildlife;
- *protection of groundwater for aquatic life;
- protection of groundwater for livestock watering; and,
- *protection of groundwater for wildlife watering.

The pathways without an asterisk (*i.e.* the direct contact pathways plus indoor vapour inhalation and livestock watering) are always included (if applicable to the land use scenario) for Unconditional Closure. The groundwater pathways marked with an asterisk may be excluded in the following circumstances:

- The indoor vapour inhalation pathway can be excluded for areas within 15 m of an oilfield wellhead. This is based on the EUB guidance for construction setbacks from current or former wellheads.
- The human ingestion of groundwater pathway may be excluded if either i) the site is not underlain by a domestic use aquifer as defined by current AENV policy (AENV, 2001b), or ii) the contaminated material is not hydraulically connected to any underlying DUA. A 5 m thickness of massive, unfractured saturated Fine-grained material, with a bulk hydraulic conductivity less than 10^{-7} m/s is considered sufficient to ensure isolation between groundwater units). **Contamination of a DUA**

beyond Canadian Drinking Water Guidelines triggers remedial activity. Sites where contamination has compromised a DUA are not eligible for a Reclamation Certificate. Proponents wishing to exclude the human ingestion of groundwater pathway should familiarize themselves with the definition of a DUA laid out in AENV (2001b). As a guide, water-bearing units with a horizontal hydraulic conductivity less than 10^{-6} m/s are unlikely to be considered a DUA.

- The protection of groundwater for freshwater aquatic life and for wildlife watering pathways may both be excluded in cases where there is no surface water body (*e.g.*, creek, lake, slough, etc.) within 300 m downgradient of the site. Downgradient is defined as any direction within 45 degrees either side of the direction of groundwater flow.

These exclusions are permitted because they remove pathways that are not applicable based on stable hydrogeological or hydrological features of a site. Accordingly, excluding these pathways allows full protection of human and ecological receptors without any restrictions on the future use of a site.

DRAFT

2.7 Selection of Chemicals of Concern

The chemicals of concern covered by these guidelines are non-polar hydrocarbon compounds and include the following:

- benzene;
- toluene;
- ethylbenzene;
- xylenes;
- Petroleum Hydrocarbon (PHC) Fraction F1 ($C_6 - C_{10}$, excluding benzene, toluene, ethylbenzene, and xylenes (BTEX), as defined by CCME, 2000a);
- PHC Fraction F2 ($C_{>10} - C_{16}$, as defined by CCME, 2000a);
- PHC Fraction F3 ($C_{>16} - C_{34}$, as defined by CCME, 2000a);
- PHC Fraction F4 ($C_{>34}$, as defined by CCME, 2000a); and,
- carcinogenic polycyclic aromatic hydrocarbons (PAHs), quantified as equivalent benzo(a)pyrene (B(a)P).

Note that carcinogenic PAHs are not included in the definitions of PHC fractions F1 to F4. Analysis for carcinogenic PAHs may or may not be required, but if so, concentrations of PAHs are not subtracted from concentrations of F3, as discussed in the following Section.

2.7.1 Determining Whether PAH Analysis is Required

Analysis for carcinogenic PAHs is required at sites where there is a reasonable expectation that such contamination may be an issue. Two main factors are considered in determining whether analysis for carcinogenic PAHs is required:

- ***Presence of Human Receptors*** – the cancer endpoint is only considered for humans. If the land use is natural area, only ecological pathways plus the protection of potable groundwater are considered. Since the non carcinogenic effects of these PAHs are included in fraction F3, and no guideline is calculated for the protection of potable groundwater for carcinogenic PAHs, it follows that there is no requirement for PAH analysis at upstream oil and gas sites in natural area land use.
- ***Hydrocarbon Type*** – lighter hydrocarbons, such as gasoline, condensate, and petroleum solvents will not generally include significant PAHs (EC, 1992). Heavier hydrocarbons including crude oil, fuel oil, diesel, and waste oil, and unknown hydrocarbon mixtures may contain PAHs (EC, 1992).

Professional judgement should be exercised to determine whether PAH analysis is required at a particular site. The hydrocarbon type should be taken into account, together with the type of facility. Examples of upstream facilities or parts of facilities where PAH contamination could be expected include, but are not limited to flare pits, wax pits, soil subjected to flare stack carry-over, fire training areas, floor drains, sumps, tank bottom sludges, process vessel sludges, landfills, and drilling sumps where diesel-based mud was used.

DRAFT

Once the likelihood of PAH contamination has been estimated, and if the land use is agricultural, residential, commercial, or industrial, then one of the following three possibilities for PAH characterization should be selected:

1. Carcinogenic PAHs are expected to be present at a site and sufficient analyses are performed to characterize their nature and extent.
2. One or more sources of hydrocarbon that may contain carcinogenic PAHs are present at a site. One worst case sample is analyzed from each source region. If carcinogenic PAHs are below guideline levels in these samples, no further PAH analysis is required. If carcinogenic PAHs are present above guideline levels, then further delineation of PAHs will be required.
3. The source(s) of hydrocarbon contamination is (are) known and do not contain carcinogenic PAHs; in this case no PAH analysis need be undertaken.

When analysis for carcinogenic PAHs is required, the eight compounds to be analyzed are those listed in Table 2.

The definition of the four PHC fractions (CCME, 2000a) specifically excludes carcinogenic PAHs. However, for the Alberta hydrocarbon guidelines there is no provision to subtract the concentrations of carcinogenic PAHs (if measured) from the concentrations of PHC fractions. The reasons for this are two-fold: 1) in general, carcinogenic PAHs will form a small fraction of the overall mass of PHC in a sample, and subtracting them will make negligible difference to the concentration of the PHC fractions; and, 2) subtracting PAHs from F3 would only apply to human health pathways, and so the concentrations of the PHC fractions to be used would depend on whether a human health or ecological pathway was limiting for that chemical. Such an approach would be difficult to manage and confusing, and is not used.

2.7.2 Expressing PAHs as Equivalent B(a)P Concentration

It would be unnecessarily cumbersome to apply separate guidelines for each of the carcinogenic PAHs listed in Table 2. The guidelines adopt a standard approach (*e.g.,* BCMELP, 1988; USEPA, 1993) in that the carcinogenic potency of each compound is expressed relative to B(a)P. The concentrations of the eight carcinogenic PAHs are reduced to an equivalent concentration of B(a)P by multiplying each by its relative carcinogenic potency and summing:

$$C_{B(a)P} = \sum_i C_i RCP_i$$

Where:

$C_{B(a)P}$ = equivalent concentration of B(a)P (mg/kg);
C_i = concentration of 'i'th carcinogenic PAH (mg/kg); and,
RCP_i = relative carcinogenic potency of 'i'th carcinogenic PAH (mg/kg, Table 2).

DRAFT

An example of this process is included in Case Study I.

2.8 Subsoil Guidelines

In this project, consistent with the approach taken in CCME (2000a), separate guidelines are provided for surface soils and subsoils. Subsoils are defined as being soils at a depth greater than 1.5 m. The rationale for distinguishing surface soils and subsoils is that: i) some of the direct contact pathways apply only to surface soils; and, ii) for some pathways (*e.g.,* plant/invertebrate soil contact, indoor air inhalation) a less stringent guideline may be appropriate in subsoil to achieve the same level of protection as that achieved in surface soil. However, subsoil guidelines are only applicable as long as subsoil remains at a depth of greater than 1.5 m. This issue is discussed further in Sections 4.1.3 and 5.2.1.

3. SITE ASSESSMENT

3.1 Sampling

The aim of a site assessment program is to adequately characterize the nature (*i.e.*, compounds present) and extent (areal and vertical) of contamination. The BTEX compounds and hydrocarbon fractions F1 and F2 are volatile, and so sampling protocols that minimize the loss of volatile compounds from soil and groundwater samples must be used. Site assessment methodology must follow the protocol set out in:

- *Phase 1 Environmental Site Assessment Guideline for Upstream Oil and Gas Sites.* (AENV 2001c).

In addition, sampling and analysis should follow:

- *Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites. Volumes 1 and 2* (CCME, 1993).

Determination of the dominant soil type is a critical step in determining the appropriate set of guidelines to be used at a site (see Section 2.4). The number of texture measurements required to determine the dominant soil type at a site will depend on the textural complexity of that site as shown in the borehole logs from the site assessment. As a guide, the soil type of at least three samples should be determined from each distinct textural unit at a site. As indicated in Section 2.4, the presence of continuous or extensive lenses of coarse textured material will generally lead to a "coarse" designation for the entire site.

3.2 Analytical Requirements

DRAFT

Chemical analysis may be required for BTEX in soil and water, for PHC fractions F1 to F4 in soil, PHC fractions F1 and F2 in water, and PAHs in soil and water.

Analyses should be undertaken by a laboratory accredited by the Canadian Association of Environmental Analytical Laboratories (CAEAL). Certified and accredited methods should be used for BTEX analysis in soil and water. The analytical method for PHC fractions F1 to F4 in soil is defined by CCME (2000c). Analysis of PHC fraction F1 in water should be done using a certified and accredited method for total purgeable hydrocarbons C_6-C_{10}, with the concentration of BTEX compounds subtracted. Analysis of PHC fraction F2 in water should be done using a standard method for total extractable hydrocarbons C_{10}-C_{16}. Analysis of the eight PAHs listed in Table 2 should be done using a certified and accredited method.

Because the CCME Canada-Wide Standard for Petroleum Hydrocarbons in Soil was endorsed by Ministers in May 2001, there has not been sufficient time for all applicant laboratories to be assessed by CAEAL. In the interim, analyses should be directed to CAEAL-accredited laboratories and those that have applied for CAEAL accreditation.

4. USING TIER 1 GUIDELINES

It is anticipated that the majority of sites will be assessed using Tier 1 guidelines. The following Sections explain how the applicable Tier 1 guidelines for a particular site are determined.

4.1 Soil

4.1.1 Applicability of Tier 1 Guidelines

The first decision to be made is whether Tier 1 guidelines are applicable at a site. The assumptions used in the generation of Tier 1 guidelines are conservative, and will be applicable to the majority of sites in Alberta. At sites where the assumptions are not applicable, however, Tier 1 guidelines can not be used, and a Tier 2 or Tier 3 approach must be used. Examples of situations where Tier 1 guidelines would not apply include:

- sites where the soils are predominantly coarse sands and gravels, with bulk hydraulic conductivity greater than 10^{-5} m/s; and,
- sites where the land use does not fall into any of five generic land use scenarios.

4.1.2 Tier 1 Decision Tree

The Tier 1 guidelines for Fine and Coarse surface soil are included in Tables 3 and 4, respectively. The Tier 1 guidelines for Fine and Coarse subsoil are included in Tables 5 and 6, respectively. A five step "Decision Tree" is used to simplify the four tables noted above to the applicable guideline value for each chemical of concern at a site. The Decision Tree is presented in Figure 2. The five steps are as follows:

1. Determine whether subsoil guidelines are applicable at the site. Subsoil guidelines are only applicable at Tier 1 within 15 m of an oilfield wellhead. If subsoil guidelines are not applicable, then surface soil guidelines are used for all soil depths, and the applicable guidelines are found in Tables 3 or 4. If subsoil guidelines are applicable, then they are found in Tables 5 or 6.
2. Identify soil type (Section 2.4). Guidelines for Fine soils will be found in Tables 3 and 5 for surface soils and subsoils, respectively. Guidelines for Coarse soils will be found in Tables 4 and 6 for surface soils and subsoils, respectively.
3. Select land use (Section 2.5). Guidelines for each of the five land uses are found in separate blocks of each Table.
4. Exclude any inapplicable pathways (Section 2.6).
5. Select the smallest remaining guideline for each chemical.

DRAFT

Taking as an example a case where subsoil guidelines are not applicable, Step 1 reduces the four possible Tables to two; Step 2 identifies the single Table containing the applicable guidelines for a site; Step 3 identifies the applicable guideline block; Step 4 may reduce the number of pathways in that guideline block, and Step 5 identifies the single guideline applicable to each chemicals of concern at the site.

Once the guideline for each chemical or group has been determined, they can be used to define the extent of contaminated soil at a site. At the majority of sites, the next step will be to remediate any soil contaminated above guideline levels, and then to seek regulatory acceptance. However, at some sites a proponent may wish to consider developing site-specific guidelines at Tier 2 or Tier 3. The proponent would weigh the additional effort of collecting further site data and developing guidelines against possible savings in remedial effort. Tier 2 and 3 approaches are discussed in Sections 5 and 6, respectively.

This Tier 1 soil guideline selection process is illustrated in Case Studies I and II.

4.1.3 Subsoil Guidelines

Subsoil guidelines are summarized in Tables 5 and 6 for Fine and Coarse soils, respectively. Subsoil guidelines are only available at Tier 1 within the 15 m setback from an oilfield wellhead in natural area or agricultural land uses. Subsoil guidelines may be available at Tiers 2B or 3B, once the regulatory framework for these Management Levels is finalized.

4.2 Groundwater

Acceptable levels of chemicals of concern in groundwater are dependant on potential groundwater use. Table 7 provides groundwater guidelines for four potential water uses: human drinking water, freshwater aquatic life, livestock watering, and wildlife watering. Note that two sets of groundwater guidelines are provided for freshwater aquatic life and wildlife watering pathways. One guideline applies to groundwater measurements from monitoring wells located at least 10 m from a surface water body. The other guideline is for piezometers located within 10 m of a surface water body. Note also that at Fine sites, there is no freshwater aquatic life or wildlife watering guideline for groundwater at least 10 m from the nearest surface water body. This reflects the limited mobility of hydrocarbons in Fine soils.

DRAFT

The groundwater guideline for a site is the lowest of the guidelines for applicable groundwater uses. Applicability is defined as follows:

- The human drinking water guideline is applicable whenever groundwater contamination is present in either i) a domestic use aquifer (DUA), or ii) a groundwater unit hydraulically connected to a DUA. (5 m of saturated Fine-grained material, with a bulk hydraulic conductivity less than 10^{-7} m/s is considered sufficient to ensure isolation between groundwater units). A DUA is defined by Alberta Environment in (AENV, 2001b).
- The livestock watering guideline is applicable whenever the land use is agricultural and on grazing leases within the Green Area.
- The freshwater aquatic life and wildlife watering guidelines are applicable whenever a surface water body is present within 300 m downgradient of the site.

An example of the use of groundwater guidelines is provided in Case Study II.

Note that dilution of groundwater discharging into a moving body of water is not taken into account. This may be considered at Tier 3, with appropriate justification.

If groundwater concentrations at a site exceed guideline values, a proponent has two options:

1. implement a groundwater remediation scheme to reduce hydrocarbon concentrations to below guideline values;
2. consider a Tier 2 or Tier 3 approach.

4.3 Regulatory Acceptance

Two possible scenarios exist for regulatory acceptance at Tier 1:

- If a site assessment shows that soil and groundwater contamination is within applicable Tier 1 guideline levels, a proponent may declare the site uncontaminated and apply for a Reclamation Certificate once surface reclamation work is complete.
- If soil and/or groundwater contamination has been identified at concentrations above applicable Tier 1 guideline levels and subsequently remediated to below those levels then the proponent may declare the site remediated and apply for a Reclamation Certificate once surface reclamation work is complete.

Sites with groundwater contamination beyond applicable guidelines are not eligible for a Reclamation Certificate.

DRAFT

5. USING TIER 2 GUIDELINES

Three Management Levels are potentially available at Tier 2. These Management Levels are summarized in Table 1. Note that only Tier 2A is presently applicable -- Tiers 2B and 2C are included for discussion only.

- Tier 2A allows for re-calculating Tier 1 guidelines by replacing certain assumed parameters with measured, site-specific values. Examples of such parameters could include soil physical properties and the distance to a nearby surface water body.

- Tier 2B is not currently available, but if implemented would be used where current conditions are protective of human and environmental health, but acknowledgement of certain on-site conditions is required to ensure protection is maintained in the case of future re-development of the site. Examples of such conditions would include i) using subsoil guidelines as remedial objectives (except within the 15 m offset from an oilfield wellhead), and ii) excluding the plant/invertebrate soil contact pathway at graveled or paved sites.

- Tier 2C is not currently available, but when implemented, it will apply to sites where groundwater contamination extends off-site, and temporary land use restrictions are necessary to protect human and ecological health while the groundwater issue is resolved.

These three Management Levels are discussed in more detail below.

5.1 Tier 2A

5.1.1 Introduction

The objective of Tier 2A is to allow limited modifications to Tier 1 so that guidelines which are somewhat customized to a particular site may be generated at a relatively modest level of additional effort.

The following discussion describes how Tier 2A modifications can be made to Tier 1 guidelines. The protocols, equations and non chemical-specific values used to derive the Tier 1 guidelines are available in Volume 1. Tier 1 guideline development is explained, and chemical-specific data are provided in Volume 2. A thorough knowledge of this material will be required in order to derive Tier 2A guidelines. Before proceeding to Tier 2A, a proponent should be clear as to which pathway(s) at a site are limiting at Tier 1. The next step is to determine whether the limiting pathway(s) can be adjusted at Tier 2A. The pathways are divided into three groups:

Pathways that are rarely, if ever, expected to be limiting
- human soil ingestion;
- human soil dermal contact;
- soil ingestion by livestock or wildlife; and,
- protection of groundwater for wildlife watering.

Pathways that may be limiting, but for which no Tier 2A adjustments are permitted
- plant/invertebrate soil contact.

Pathways that may be limiting, and for which Tier 2A adjustments are permitted
- human indoor vapour inhalation;

DRAFT

- protection of potable groundwater; and,
- protection of groundwater for aquatic life or livestock watering.

If one of the pathways in the last group is limiting, then site-specific adjustments can be made to the calculation of the Tier 1 guideline to derive a Tier 2A guideline. The parameters that can be adjusted at Tier 2A are listed and discussed in the following Sections.

Examples of Tier 2A adjustments are provided in Case Study II.

5.1.2 Tier 2A Adjustments

For each of the three pathways noted above for which Tier 2A adjustments are permitted, the parameters that can be adjusted are clearly defined. These are generally the parameters that have the most significant effect on the guideline for that pathway, and are stable parameters (*e.g.*, soil, hydrogeological or meteorological parameters). If a proponent wishes to adjust other parameters, a Tier 3 site-specific risk assessment would be required. The “Tier 2A Parameters” for each pathway are adapted from CCME (2001) and discussed in the following Sections.

5.1.2.1 Human Indoor Vapour Inhalation

The guideline for this pathway is calculated using the equation in Section 3.5 of Volume 2. The Tier 2A Parameters for this pathway are as follows:

Soil Parameters

- total porosity (unitless);
- bulk density (g/cm^3);
- water content (g/g);
- air filled porosity (unitless);
- soil vapour permeability (cm^2).
- organic carbon fraction (g/g); and,

DRAFT

Other Parameters

- depth to contamination (m).

The following information should be noted by proponents intending to make a Tier 2A adjustment to the guideline for this pathway:

- Using site-specific values for the first five of the soil parameters listed above is done as a package – either measured, site-specific values are used for all these parameters, or generic values are used for all these parameters.

- The sample must be undisturbed (*e.g.,* collected in a Shelby tube) for all soil parameter measurements except the water content and organic carbon fraction measurements.
- The water content and bulk density measurements must be reported on a dry weight basis.
- Sufficient measurements of soil parameters must be made to adequately characterize the soil(s) at the site. The parameters used in recalculating the guidelines for this pathway should be conservative in relation to the range of values measured at the site.
- The option to input site-specific building parameters is not provided at Tier 2A so that the guidelines generated are protective of humans in any building that might be built on the site.

5.1.2.2 Protection of Potable Groundwater

The guideline for this pathway is calculated using the equation in Section 3.6 of Volume 2. The Tier 2A Parameters for this pathway are as follows:

Soil Parameters
- water content (g/g).

Other Parameters
- recharge rate (m/y);
- hydraulic gradient (unitless);
- saturated hydraulic conductivity of aquifer (m/y); and,
- site length (*i.e.*, length of contaminated material parallel to groundwater flow) (m).

The following information should be noted by proponents intending to make a Tier 2A adjustment to the guideline for this pathway:

- The water content must be reported on a dry weight basis.
- The local recharge rate may be estimated by taking 2% or 10% (Fine or Coarse soil, respectively) of the mean annual precipitation for a local meteorological station.
- The hydraulic gradient must be representative of conditions beneath the contaminated area.
- Saturated hydraulic conductivity is measured using standard field techniques.
- Sufficient measurements of saturated hydraulic conductivity must be made to be able to estimate the range of this parameter within the aquifer. The value used to calculate the Tier 2A guideline should be conservative, *i.e.*, represent the lower end of the range of measured values.

DRAFT

5.1.2.3 Protection of Groundwater for Aquatic Life or Livestock Watering

The guideline for this pathway is calculated using the equation in Section 4.3 of Volume 2. The Tier 2A Parameters for this pathway are as follows:

Soil Parameters

- total porosity (unitless);
- bulk density (g/cm^3);
- water content (g/g);
- air filled porosity (unitless); and,
- organic carbon fraction (g/g).

Other Parameters

- recharge-rate (m/y);
- hydraulic gradient (unitless);
- saturated hydraulic conductivity of aquifer (m/y);
- site length (*i.e.*, length of contaminated material parallel to groundwater flow) (m);
- site width (*i.e.*, width of contaminated material perpendicular to groundwater flow) (m);
- thickness of affected soils (m);
- thickness of unsaturated zone (m);
- distance from top of affected soils to groundwater (m); and,
- distance to nearest surface water (freshwater aquatic life only; m).

The following information should be noted by proponents intending to make a Tier 2A modification to the guideline for this pathway:

- Using site-specific values for the soil parameters listed above is done as a package – either measured, site-specific values are used for all these parameters, or generic values are used for all these parameters.
- The sample must be undisturbed (*e.g.*, collected in a Shelby tube) for measurements of all soil parameters except the water content and organic carbon fraction measurements.
- The water content and bulk density measurements must be reported on a dry weight basis.
- Sufficient measurements of soil parameters must be made to adequately characterize the soil at the site. The parameters used in recalculating the guidelines for this pathway should be conservative in relation to the range of values measured at the site.
- The local recharge rate may be estimated by taking 2% or 10% (Fine or Coarse soil, respectively) of the mean annual precipitation for a local meteorological station.
- The hydraulic gradient must be representative of conditions beneath the contaminated area.
- Saturated hydraulic conductivity is measured using standard field techniques.

DRAFT

- Sufficient measurements of saturated hydraulic conductivity must be made to be able to estimate the range of this parameter within the aquifer. The value used to calculate the Tier 2A guideline should be conservative, *i.e.,* represent the upper end of the range of measured values.
- The distance downgradient to the nearest receptor for the groundwater protection for *livestock watering* pathway cannot be changed at Tier 2A. (This parameter *can* be adjusted to recalculate the protection of groundwater for *freshwater aquatic life* guideline).

5.1.2.4 Adjusting Hydrocarbon Composition

Tier 1 guidelines are based on an assumed composition of each hydrocarbon fraction (F1 to F4). Details of this assumed composition are included in Volume 1. It is permissible at Tier 2A to re-calculate any of the Tier 1 guidelines except the soil ecological contact guideline, based on the measured composition of each hydrocarbon fraction. (The soil ecological contact pathway is based on measured toxicity data for plants and invertebrates exposed to fractions F1 to F4, and accordingly there is no scope to adjust the hydrocarbon composition for this guideline.) Such a re-calculation requires a determination of the concentration of each hydrocarbon sub-fraction in representative sample(s) of contaminated material. The sub-fractions are defined by the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG, 1997). A method for this analysis has been developed by the Atlantic Partners in Risk Based Corrective Action Implementation (Atlantic PIRI, 1999).

5.1.3 Tier 2A Groundwater Guidelines

At Tier 2A, the Tier 1 groundwater guidelines (Table 7) are used with one change. For the groundwater guideline for the protection aquatic life, a site-specific guideline may be calculated based on the actual minimum distance from the dissolved phase plume to the nearest surface water body.

5.1.4 Regulatory Acceptance

Tier 2A guidelines generated by inputting site-specific values for the parameters noted above do not require any engineered or institutional controls in order to provide a similar level of protection for human and ecological receptors to that targeted by Tier 1. Accordingly, Tier 2A guidelines can be used for Unconditional Closure, and a proponent who has remediated a site to accepted Tier 2A guidelines may apply for Reclamation Certificate.

DRAFT

5.2 Tier 2B

Tier 2B is not currently available, as the consultation process with stakeholders is ongoing. An overview of what is being planned for Tier 2B is included to give proponents an idea of what may become available in the future. Tier 2B options would only be available to proponents who had care and control of a site, and so may have limited application at upstream oil and gas sites, where many of

DRAFT

the facilities are on leased land. The remainder of this Section is italicized to emphasize the fact that it is not available at present.

Tier 2B is applicable in 2 situations, as described in the two following Sections.

5.2.1 Subsoil Guidelines

Subsoil guidelines are presented in Tables 5 and 6 for Fine and Coarse soil, respectively. Subsoil guidelines are only protective while subsoil remains at depths greater than 1.5 m. The use of subsoil guidelines within the 15 m offset in natural areas or agricultural land use is available at Tier 1 and was discussed in Section 4.1.3. In all other situations, passive on-site management (i.e., ensuring that subsoil is not disturbed) will be required if subsoil guidelines are included in the remediation objectives for a site.

If subsoil guidelines are used at a site, a record of this situation is required to ensure that future developers of the site are aware of the situation

5.2.2 Ecological Soil Contact Pathway Suspended at Paved or Gravelled Sites

It is common practice for parts of certain upstream facilities (e.g., gas plants) to be paved or graveled. Plant growth in these areas is often not required or actively discouraged to control fire hazard. At such sites, there is no requirement for the soil to support an ecological function, and accordingly the surface soil plant/invertebrate soil contact pathway can be suspended. It should be noted, however, that in such cases the subsoil plant/invertebrate soil contact pathway would be applicable to both surface and subsoil, because the guidelines for this pathway include qualitative consideration of other issues, including aesthetics and protection of buried infrastructure.

If the surface soil plant/invertebrate soil contact pathway is suspended at a site, a record of this situation is required to ensure that future developers of the site are aware of the situation..

5.3 Tier 2C

Tier 2C is not currently available, as the regulatory and scientific basis for its application are still being developed. An overview of what is being planned for Tier 2C is included to give proponents an idea of what may become available in the future. The remainder of this Section is italicized to emphasize the fact that it is not available at present.

Tier 2C is anticipated to apply at a site where contaminated soil has generated an off-site groundwater plume with hydrocarbon concentrations above Tier 1 groundwater guidelines.

DRAFT

Remediation of soil contamination to Unconditional Closure guidelines will normally be required. In many cases, natural attenuation of the dissolved hydrocarbon plume will reduce concentrations in groundwater below applicable guidelines within a reasonable time. Provisions are required to ensure that human and ecological exposure is eliminated (e.g., by prohibiting groundwater usage within the plume area) until groundwater concentrations are compliant.

5.3.1 Requirements

The requirements for a site to be considered for Conditional Closure under the Groundwater Plume Scenario are as follows:

Sources *- contaminant sources, including soils contaminated above Unconditional Closure guidelines and any free product, have been remediated or removed.*

Groundwater *– Tier 2C Closure would apply to sites with concentrations of hydrocarbons in groundwater above applicable guidelines.*

Plume Stability *– the proponent must demonstrate that the Groundwater Plume (defined as the areal extent of groundwater contaminated above applicable guidelines) is stable or shrinking.*

Expectation of Attenuation *– the proponent must demonstrate that that there is a reasonable expectation that the groundwater plume will attenuate naturally to the point where contaminant concentrations in groundwater fall below unconditional guidelines within a reasonable period of time (normally 10 years).*

Salinity Requirement *- groundwater salinity is below 4,000 ppm of total dissolved solids (TDS).*

Required Controls *- appropriate controls, negotiated between all stakeholders, are in place to ensure that no receptors have access to groundwater from within the Groundwater Plume during the period of Conditional Closure; this restriction implies that no groundwater wells can be installed or dugouts excavated in this area, and any existing wells or dugouts cannot be used for the duration of the Conditional Closure.*

Closure Piezometers *– the proponent must identify an appropriate number of piezometers ("Closure Piezometers") that are representative of the highest groundwater concentrations at the site. These piezometers will be used to determine when groundwater concentrations have decreased to within applicable guideline values, and hence when Unconditional Closure has been achieved and a letter of compliance can be issued. It is anticipated that at small, simple, well-characterized sites, a single Closure Piezometer located close to the source on the main plume axis will be sufficient. Larger or more complex sites will require more Closure Piezometers.*

DRAFT

5.3.2 Regulatory Acceptance

If the conditions noted in Section 5.3.1 above are met at a site, the proponent can apply to AENV for a Management Plan Acceptance Letter. If the application is successful, and the landowner agrees to the plan, then the period of Conditional Closure can begin. There is no requirement for ongoing groundwater monitoring during Conditional Closure, as the plume has already been demonstrated to be stable or shrinking, and controls are in place to restrict human or ecological exposure to contaminated groundwater.

Confirmatory sampling to demonstrate that groundwater concentrations have reduced to below applicable guideline values must be conducted within 10 years, unless another time frame is agreed between all stakeholders. Confirmatory sampling will involve three groundwater sampling events. Three sets of samples will be analyzed from each Closure Piezometer, for all parameters that were previously present above guideline levels. The three sampling events shall be completed intervals of approximately six months, to allow an assessment of seasonal variability. If the hydrocarbon concentrations in all three samples are below applicable guidelines, the site is eligible for Unconditional Closure.

6. SITE-SPECIFIC (TIER 3) REMEDIATION OBJECTIVES

There may be sites where the amount of flexibility available under Tier 1 or Tier 2 is insufficient to adequately represent the complexity of processes occurring and pathways to be considered. In such cases a proponent may elect to develop Tier 3 site-specific remediation objectives. In deciding to proceed to Tier 3, a proponent will evaluate the additional required site assessment and site-specific risk assessment work against savings from a possible relaxation of Tier 1 or Tier 2 guideline values. At Tier 3, a proponent has the flexibility to use a wide range of approaches to represent site-specific conditions and processes. However the proponent is required to provide a rigorous scientific justification for any methodology used.

At Tier 3, the same high level of protection for humans and ecological receptors is required as at Tiers 1 and 2. Three Management Levels are distinguished at Tier 3, analogous to the three Management Levels available at Tier 2. Note that Tier 3B is not currently available, and accordingly is italicized below.

Tier 3A. At Tier 3A, more detailed site-specific information, which could include site-specific toxicity information, and/or the use of different models, are used to develop site-specific remediation objectives (SSROs). The protection of human and ecological receptors is achieved without the need for engineered or institutional controls. The same environmental protection goals used at Tier 1 apply. All pathways and receptors considered at Tier 1 must be included as well as any that are important and particular to the site under consideration.

Tier 3B. Tier 3B is similar to Tier 3A, but including one or more of the issues discussed under Tier 2B. Tier 3B can be used to address situations where on-site contamination is present above Tier 1 levels, but human and ecological health are protected so long as certain passive management practices remain in place, such as leaving the site paved, or leaving subsoil undisturbed. At Tier 3B, successful remedial efforts can be acknowledged by a Letter of Compliance (On-Site Management). This option is not available at present.

Tier 3C. In Tier 3C risk assessments, the protection of human and ecological receptors is achieved partly through the use of engineered or institutional controls. Tier 3C risk assessments are not eligible for a Reclamation Certificate.

Providing detailed guidance for site-specific risk assessment is outside the scope of this project. Much provincial and federal guidance is available on this subject, but this material will be familiar to risk assessment professionals and is not repeated here.

DRAFT

7. REFERENCES

AENV (Alberta Environment), 1995. Reclamation Criteria for Wellsites and Associated Facilities – 1995 Update. C&R/IL/95-3. April, 1995.

AENV (Alberta Environment), 2000a. A Proposed Management Framework for Reclamation and Remediation of Oil and Gas Exploration and Production Sites in Alberta. Environmental Sciences Division, Environmental Service. 4 January 2000.

AENV (Alberta Environment), 2000b. Guideline for Management of Risks at Contaminated Sites in Alberta (*draft*). Environmental Sciences Division, Environmental Service. May 2000.

AENV (Alberta Environment), 2001a. Salt Contamination Assessment and Remediation Guidelines. Pub. No. T/606. May, 2001.

AENV(Alberta Environment), 2001b Alberta Groundwater Quality Objectives (*in preparation*).

AENV(Alberta Environment), 2001c Phase 1 Environmental Site Assessment Guideline for Upstream Oil and Gas Sites. Report # ESD/LM/01-1. Pub. No. T/573. April, 2001.

Atlantic PIRI (Partners in RBCA Implementation) 1999. Guidelines for Laboratories, Tier 1 and Tier 2 Petroleum Hydrocarbon Methods. Draft Version 1.0. December 1999. Available at: http://www.atlanticrbca.com/

BCMELP (British Columbia Ministry of Environment, Lands and Parks), 1988. Special Waste Regulation. Waste Management Act. BC Reg. 63/88. Deposited February 18, 1988. Effective April 1, 1988.

CCME (Canadian Council of Ministers of the Environment), 1993. Guidance Manual on Sampling, Analysis, and Data Management for Contaminated Sites. Volumes 1 and 2. CCME-EPC-NCS62E/NCS66E.

CCME (Canadian Council of Ministers of the Environment), 1999. Canadian Environmental Quality Guidelines.

CCME (Canadian Council of Ministers of the Environment), 2001 Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil – User Guidance. April 2001.

CCME (Canadian Council of Ministers of the Environment), 2000a. Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale. Supporting Technical Document. December, 2000.

CCME (Canadian Council of Ministers of the Environment), 2000c, Analysis of Petroleum Hydrocarbons in Soil – CCME Tier 1 Method (*under revision*).

EC (Environment Canada), 1992. Tabs on Contaminated Sites - Tab #5: Sampling and Analysis of Hydrocarbon Contaminated Groundwater. Contaminated Sites Program – Federal Sites. March 1992.

EUB (Alberta Energy and Utilities Board), 1996. Advisory Land Use Planning Notes, Abandoned Oil and Gas Wells (Draft). October 1996.

DRAFT

EUB (Alberta Energy and Utilities Board), 1999. EUB Minimum Setback Recommendations, An Overview. March 1999.

TPHCWG (Total Petroleum Hydrocarbon Criteria Working Group), 1997. Total Petroleum Hydrocarbon Criteria Working Group Series (4 Volumes).

US EPA (U.S. Environmental Protection Agency), 1993. Provisional guidance for quantitative risk assessment of polycyclic aromatic hydrocarbons. Environmental Criteria and Assessment Office. Cincinnati, OH, Office of Health and Environmental Assessment.

DRAFT

Table 1. Management Levels

Management Level[1]	***Summary***	***Reclamation Certificate?***[2]
Tier 1	Site complies with Tier 1 surface soil guidelines. Subsoil guidelines allowed for soils below 1.5 m only in agricultural land or natural areas and only within 15m setback from wellhead.	YES
Tier 2A	Same as Tier 1, with guidelines recalculated using site-specific values for certain stable parameters (*e.g.*, soil properties, distance to creek, etc.)	YES
Tier 2B	*Acknowledgement of certain on-site conditions is required (e.g., subsoil guidelines used for soils below 1.5 m, except as specified in Tier 1 above, or ecological soil contact pathway suspended at paved or graveled sites) - NOT PRESENTLY AVAILABLE (JUNE 2001)*	*TBD*
Tier 2C	*Off-Site Management, requiring 3rd party landowner buy-in (e.g., off-site groundwater plume being managed by natural attenuation) - NOT PRESENTLY AVAILABLE (JUNE 2001)*	*NO*
Tier 3A	Site-specific risk assessment requiring no land use restrictions (*e.g.*, remediation objectives calculated based on site-specific toxicity testing or models other than those used at Tier 1).	YES
Tier 3B	*Same as Tier 3A, with acknowledgement of certain on-site conditions required as in Tier 2B - NOT PRESENTLY AVAILABLE (JUNE 2001)*	*TBD*
Tier 3C	Site-specific risk assessment/risk management requiring engineered or institutional controls to manage off-site contamination.	NO

Greyed-out entries are not presently applicable

Notes:

1. *Further details for all Management Levels available in appropriate sections of text.*
2. *A "yes" in this column implies that remediation to this management level is compatible with the issuance of a reclamation certificate. All the normal requirements for a reclamation certificate must still be met.*

TBD = to be determined

DRAFT

Table 2. Relative Carcinogenic Potency Factors for PAH Compounds

PAH Compound	***Relative Carcinogenic Potency***
Benzo[a]pyrene	1 (1)
Benzo[a]anthracene	0.1 (1)
Benzo[b]fluoranthene	0.1 (1)
Benzo[j]fluoranthene	0.1 (2)
Benzo[k]fluoranthene	0.1 (1)
Chrysene	0.0044 (3)
Dibenzo[a,h]anthracene	1.1 (1)
Indeno[1,2,3-cd]pyrene	0.2 (1)

Notes:

1. *BCMELP (1988);*
2. *assumed, based on value for B[k]F; and,*
3. *USEPA (1993).*

DRAFT

Table 3. Alberta Tier 1 Hydrocarbon Guidelines for Fine Surface Soil

Land Use	*Exposure Pathway*	*Benzene* (mg/kg)	*Toluene* (mg/kg)	*Ethyl-benzene* (mg/kg)	*Xylenes* (mg/kg)	*B(a)P* (mg/kg)	*F1* (mg/kg)	*F2* (mg/kg)	*F3* (mg/kg)	*F4* (mg/kg)
Natural Area	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	2,600	NA	NA
	Soil Contact (Plants and Invertebrates)	14	300	450	1,200	F3	**260**	**900**	**800**	**5,600**
	Soil Ingestion (Wildlife)	93	5,200	3,400	14,000	F3	11,000	10,000	17,000	11,000
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
	Protection of Groundwater for Wildlife *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
Agricultural	Human Soil Ingestion	1,200	22,000	10,000	RES	4.9	15,000	8,000	18,000	25,000
	Human Dermal Contact	2,700	RES	RES	RES	**4.3**	RES	RES	RES	RES
	Human Vapour Inhalation (basement) [1]	1.9	4,600	2,000	500	NA	940	5,200	NA	NA
	Human Vapour Inhalation (slab-on-grade) [1]	1.9	4,600	2,000	500	NA	940	5,200	NA	NA
	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	2,600	NA	NA
	Soil Contact (Plants and Invertebrates)	14	300	450	1,200	F3	**260**	**900**	**800**	5,600
	Soil Ingestion (Livestock)	33	1,800	1,200	4,900	F3	4,000	3,700	6,000	**4,000**
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
	Protection of Groundwater for Livestock	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
Residential	Human Soil Ingestion	1,200	22,000	10,000	RES	4.9	15,000	8,000	18,000	25,000
	Human Dermal Contact	2,700	RES	RES	RES	**4.3**	RES	RES	RES	RES
	Human Vapour Inhalation (basement)	1.9	4,600	2,000	500	NA	940	5,200	NA	NA
	Human Vapour Inhalation (slab-on-grade)	1.9	4,600	2,000	500	NA	940	5,200	NA	NA
	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	2,600	NA	NA
	Soil Contact (Plants and Invertebrates)	14	300	450	1,200	F3	**260**	**900**	**800**	**5,600**
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
Commercial	Human Soil Ingestion	4,400	RES	RES	RES	18	RES	29,000	RES	RES
	Human Dermal Contact	9,700	RES	RES	RES	**16**	RES	RES	RES	RES
	Human Vapour Inhalation	9	22,000	9,700	2,400	NA	4,600	25,000	NA	NA
	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	2,600	NA	NA
	Soil Contact (Plants and Invertebrates)	38	450	690	1,500	F3	**660**	**1,500**	**2,500**	**6,600**
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
Industrial	Human Soil Ingestion	4,400	RES	RES	RES	18	RES	RES	RES	RES
	Human Dermal Contact	9,700	RES	RES	RES	**16**	RES	RES	RES	RES
	Human Vapour Inhalation	9	22,000	9,700	2,400	NA	4,600	25,000	NA	NA
	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	2,600	NA	NA
	Soil Contact (Plants and Invertebrates)	38	450	690	1,500	F3	**660**	**1,500**	**2,500**	**6,600**
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA

DRAFT

Guidelines apply for all substances. Pathways apply as per Sections 2.6, 4 and 5 of this document.

Notes:

1. this pathway can be excluded within 15 m of an oilfield wellhead;

***bold** = lowest value for each chemical and land use;*

underlined = PHC guidelines adopted without change from CCME (2000);

** the potable groundwater, aquatic life, and groundwater for wildlife pathways may not apply at a given site: see text for details;*

BaP = benzo(a)pyrene;

all values are presented to two significant figures

RES = calculated value exceeds 30,000 mg/kg;

NA = not applicable;

TBD = to be determined;

F3 = ecological endpoints for B(a)P are included in the guideline for F3; and,

F1 to F4 = petroleum hydrocarbon fractions as defined by CCME (2000).

Table 4. Alberta Tier 1 Hydrocarbon Guidelines for Coarse Surface Soil

Land Use	Exposure Pathway	Benzene (mg/kg)	Toluene (mg/kg)	Ethyl-benzene (mg/kg)	Xylenes (mg/kg)	B(a)P (mg/kg)	F1 (mg/kg)	F2 (mg/kg)	F3 (mg/kg)	F4 (mg/kg)
Natural Area	Protection of Potable Groundwater *	**0.13**	1.6	**0.36**	**49**	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	8.3	24	91	90	F3	**130**	450	**400**	**2,800**
	Soil Ingestion (Wildlife)	93	5,200	3,400	14,000	F3	11,000	10,000	17,000	11,000
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	**230**	NA	NA
	Protection of Groundwater for Wildlife *	5.3	5,400	RES	RES	F3	16,000	15,000	NA	NA
Agricultural	Human Soil Ingestion	1,200	22,000	10,000	RES	4.9	15,000	8,000	18,000	25,000
	Human Dermal Contact	2,700	RES	RES	RES	**4.3**	RES	RES	RES	RES
	Human Vapour Inhalation (basement)[1]	0.077	200	88	22	NA	50	240	NA	NA
	Human Vapour Inhalation (slab-on-grade)[1]	**0.048**	120	54	**14**	NA	**30**	**150**	NA	NA
	Protection of Potable Groundwater *	**0.13**	1.6	**0.36**	**49**	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	8.3	24	91	90	F3	**130**	450	**400**	**2,800**
	Soil Ingestion (Livestock)	33	1,800	1,200	4,900	F3	4,000	3,700	6,000	4,000
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	**230**	NA	NA
	Protection of Groundwater for Livestock	2.2	2,200	16,000	25,000	F3	11,000	8,600	NA	NA
Residential	Human Soil Ingestion	1,200	22,000	10,000	RES	4.9	15,000	8,000	18,000	25,000
	Human Dermal Contact	2,700	RES	RES	RES	**4.3**	RES	RES	RES	RES
	Human Vapour Inhalation (basement)	0.077	200	88	22	NA	50	240	NA	NA
	Human Vapour Inhalation (slab-on-grade)	**0.048**	120	54	**14**	NA	**30**	**150**	NA	NA
	Protection of Potable Groundwater *	0.13	1.6	**0.36**	49	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	8.3	24	91	90	F3	130	450	**400**	**2,800**
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	230	NA	NA
Commercial	Human Soil Ingestion	4,400	RES	RES	RES	18	RES	29,000	RES	RES
	Human Dermal Contact	9,700	RES	RES	RES	**16**	RES	RES	RES	RES
	Human Vapour Inhalation	0.55	1,400	630	160	NA	**310**	1,700	NA	NA
	Protection of Potable Groundwater *	**0.13**	1.6	**0.36**	**49**	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	13	71	200	130	F3	330	760	**1,700**	**3,300**
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	**230**	NA	NA
Industrial	Human Soil Ingestion	4,400	RES	RES	RES	18	RES	RES	RES	RES
	Human Dermal Contact	9,700	RES	RES	RES	**16**	RES	RES	RES	RES
	Human Vapour Inhalation	0.55	1,400	630	160	NA	**310**	1,700	NA	NA
	Protection of Potable Groundwater *	**0.13**	1.6	**0.36**	**49**	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	13	71	200	130	F3	330	760	**1,700**	**3,300**
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	**230**	NA	NA

DRAFT

Guidelines apply for all substances. Pathways apply as per Sections 2.6, 4 and 5 of this document.

Notes:

1. this pathway can be excluded within 15 m of an oilfield wellhead;
***bold** = lowest value for each chemical and land use;*
underlined = PHC guidelines adopted without change from CCME (2000);
** the potable groundwater, aquatic life, and groundwater for wildlife pathways may not apply at a given site: see text for details;*
BaP = benzo(a)pyrene;
all values are presented to two significant figures
RES = calculated value exceeds 30,000 mg/kg;
NA = not applicable;
TBD = to be determined; and,
F3 = ecological endpoints for B(a)P are included in the guideline for F3; and,
F1 to F4 = petroleum hydrocarbon fractions as defined by CCME (2000).

Table 5. Alberta Hydrocarbon Guidelines for Fine Subsoil
*Applicable below 1.5 m depth within 15 m radius of wellhead**

Land Use	Exposure Pathway	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	Xylenes (mg/kg)	B(a)P (mg/kg)	F1 (mg/kg)	F2 (mg/kg)	F3 (mg/kg)	F4 (mg/kg)
Natural Area [1]	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	2,600	NA	NA
	Soil Contact (Plants and Invertebrates)	28	300	450	1,200	F3	**750**	**2,200**	**3,500**	**10,000**
	Soil Ingestion (Wildlife)	NA	NA	NA	NA	F3	NA	NA	NA	NA
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
	Protection of Groundwater for Wildlife *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
Agricultural [1]	Human Soil Ingestion	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Dermal Contact	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Vapour Inhalation (basement) [2]	1.9	4,600	2,000	500	NA	940	5,200	NA	NA
	Human Vapour Inhalation (slab-on-grade) [2]	1.9	4,800	2,100	520	NA	990	5,500	NA	NA
	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	2,600	NA	NA
	Soil Contact (Plants and Invertebrates)	28	300	450	1,200	F3	**750**	**2,200**	**3,500**	**10,000**
	Soil Ingestion (Livestock)	NA	NA	NA	NA	F3	NA	NA	NA	NA
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
	Protection of Groundwater for Livestock	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
Residential	Human Soil Ingestion	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Dermal Contact	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Vapour Inhalation (basement)	1.9	4,600	2,000	500	NA	940	5,200	NA	NA
	Human Vapour Inhalation (slab-on-grade)	1.9	4,800	2,100	520	NA	990	5,500	NA	NA
	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	2,600	NA	NA
	Soil Contact (Plants and Invertebrates)	28	300	450	1,200	F3	**750**	**2,200**	**3,500**	**10,000**
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
Commercial	Human Soil Ingestion	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Dermal Contact	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Vapour Inhalation	9	23,000	9,800	2,500	NA	4,800	26,000	NA	NA
	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	**2,600**	NA	NA
	Soil Contact (Plants and Invertebrates)	77	450	690	1,500	F3	**1,000**	3,000	**5,000**	**10,000**
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA
Industrial	Human Soil Ingestion	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Dermal Contact	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Vapour Inhalation	9	23,000	9,800	2,500	NA	4,800	26,000	NA	NA
	Protection of Potable Groundwater *	**0.073**	**0.86**	**0.19**	**25**	NA	1,900	**2,600**	NA	NA
	Soil Contact (Plants and Invertebrates)	77	450	690	1,500	F3	**1,000**	3,000	**5,000**	**10,000**
	Protection of Groundwater for Aquatic Life *	RES	RES	RES	RES	F3	TBD	TBD	NA	NA

DRAFT

uidelines apply for all substances. Pathways apply as per Sections 2.6, 4 and 5 of this document.

otes: 1. subsoil guidelines are available at Tier 1 within 15 m of wellhead in natural area and agricultural; otherwise Tier 2B management is required.

2. this pathway can be excluded within 15 m of an oilfield wellhead;

***bold** = lowest value for each chemical and land use;*
underlined = PHC guidelines adopted without change from CCME (2000);
** the potable groundwater, aquatic life, and groundwater for wildlife;*
pathways may not apply at a given site: see text for details;

all values are presented to two significant figures
RES = calculated value exceeds 30,000 mg/kg;
NA = not applicable;
TBD = to be determined; and

BaP = benzo(a)pyrene
F3 = ecological endpoints for B(a)P are included in F3; and,
F1 to F4 = petroleum hydrocarbon fractions defined by CCME (2000c)

Table 6. Alberta Hydrocarbon Guidelines for Coarse Subsoil

Applicable below 1.5 m depth within 15 m radius of wellhead

DRAFT

Land Use	Exposure Pathway	Benzene (mg/kg)	Toluene (mg/kg)	Ethyl-benzene (mg/kg)	Xylenes (mg/kg)	B(a)P (mg/kg)	F1 (mg/kg)	F2 (mg/kg)	F3 (mg/kg)	F4 (mg/kg)
Natural Area [1]	Protection of Potable Groundwater *	**0.13**	1.6	**0.36**	**49**	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	17	48	180	180	F3	**350**	1,500	**2,500**	**10,000**
	Soil Ingestion (Wildlife)	NA	NA	NA	NA	F3	NA	NA	NA	NA
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	**230**	NA	NA
	Protection of Groundwater for Wildlife *	5.3	5,400	RES	RES	F3	16,000	15,000	NA	NA
Agricultural [1]	Human Soil Ingestion	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Dermal Contact	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Vapour Inhalation (basement) [2]	0.077	200	88	22	NA	50	240	NA	NA
	Human Vapour Inhalation (slab-on-grade) [2]	**0.054**	140	61	**15**	NA	**40**	**190**	NA	NA
	Protection of Potable Groundwater *	**0.13**	1.6	**0.36**	**49**	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	17	48	180	180	F3	**350**	1,500	**2,500**	**10,000**
	Soil Ingestion (Livestock)	NA	NA	NA	NA	F3	NA	NA	NA	NA
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	**230**	NA	NA
	Protection of Groundwater for Livestock	2.2	2,200	16,000	25,000	F3	11,000	8,600	NA	NA
Residential	Human Soil Ingestion	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Dermal Contact	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Vapour Inhalation (basement)	0.077	200	88	22	NA	50	240	NA	NA
	Human Vapour Inhalation (slab-on-grade)	**0.054**	140	61	**15**	NA	**40**	**190**	NA	NA
	Protection of Potable Groundwater *	0.13	1.6	**0.36**	49	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	17	48	180	180	F3	350	1,500	**2,500**	**10,000**
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	230	NA	NA
Commercial	Human Soil Ingestion	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Dermal Contact	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Vapour Inhalation	0.58	1,500	660	170	NA	**340**	1,800	NA	NA
	Protection of Potable Groundwater *	**0.13**	1.6	**0.36**	**49**	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	25	140	390	260	F3	700	2,000	**3,500**	**10,000**
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	**230**	NA	NA
Industrial	Human Soil Ingestion	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Dermal Contact	NA	NA	NA	NA	NA	RES	RES	RES	RES
	Human Vapour Inhalation	0.58	1,500	660	170	NA	**340**	1,800	NA	NA
	Protection of Potable Groundwater *	**0.13**	1.6	**0.36**	**49**	NA	3,700	5,100	NA	NA
	Soil Contact (Plants and Invertebrates)	25	140	390	260	F3	700	2,000	**3,500**	**10,000**
	Protection of Groundwater for Aquatic Life *	1.6	**0.16**	79	59	F3	360	**230**	NA	NA

uidelines apply for all substances. Pathways apply as per Sections 2.6, 4 and 5 of this document.

otes: 1. subsoil guidelines are available at Tier 1 within 15 m of wellhead in natural area and agricultural; otherwise Tier 2B management is required.

2. this pathway can be excluded within 15 m of an oilfield wellhead;

***bold** = lowest value for each chemical and land use;*

underlined = PHC guidelines adopted without change from CCME (2000);

** the potable groundwater, aquatic life, and groundwater for wildlife; pathways may not apply at a given site: see text for details;*

all values are presented to two significant figures

RES = calculated value exceeds 30,000 mg/kg;

NA = not applicable;

TBD = to be determined; and

BaP = benzo(a)pyrene

F3 = ecological endpoints for B(a)P are included in F3; and,

F1 to F4 = petroleum hydrocarbon fractions defined by CCME (2000c)

F1 to F4 = petroleum hydrocarbon fractions as defined by CCME (2000).

Table 7. Alberta Hydrocarbon Guidelines for Groundwater

Criteria	*Benzene (mg/L)*	*Toluene (mg/L)*	*Ethylbenzene (mg/L)*	*Xylenes (mg/L)*	*B(a)P (mg/L)*	*F1 (mg/L)*	*F2 (mg/L)*
All Soils							
Human Drinking Water	0.005	0.024	0.0024	0.3	0.00001	4.6	2.1
Livestock Watering	0.51	29	19	76	NA	62	57
All Soils; Piezometers <10 m from Surface Water Body							
Freshwater Aquatic Life	0.370	0.002	0.090	0.180	NA	ND	ND
Wildlife Watering	1.2	69	45	180	NA	150	140
Coarse Soils; Piezometers >10 m from Surface Water Body							
Freshwater Aquatic Life	0.53	0.021	4.8	3.3	NA	NG	NG
Wildlife Watering	1.8	NG	NG	NG	NA	NG	NG
Fine Soils; Piezometers >10 m from Surface Water Body							
Freshwater Aquatic Life	NG	NG	NG	NG	NA	NG	NG
Wildlife Watering	NG	NG	NG	NG	NA	NG	NG

Notes:
NG = no guideline required for this pathway – limited by solubility from ever exceeding surface water criterion at 10 m offset;
NA = not applicable;
ND = not determined, due to uncertainties with the critical body residue method of determining aquatic toxicity; and,
see Volume 2 of this project for further explanation of values in this Table.

DRAFT

FIGURE 1. REGULATORY PROCESS FOR TIER 1, TIER 2, AND TIER 3 GUIDELINES
(Adapted from AENV, 2000b)

DRAFT

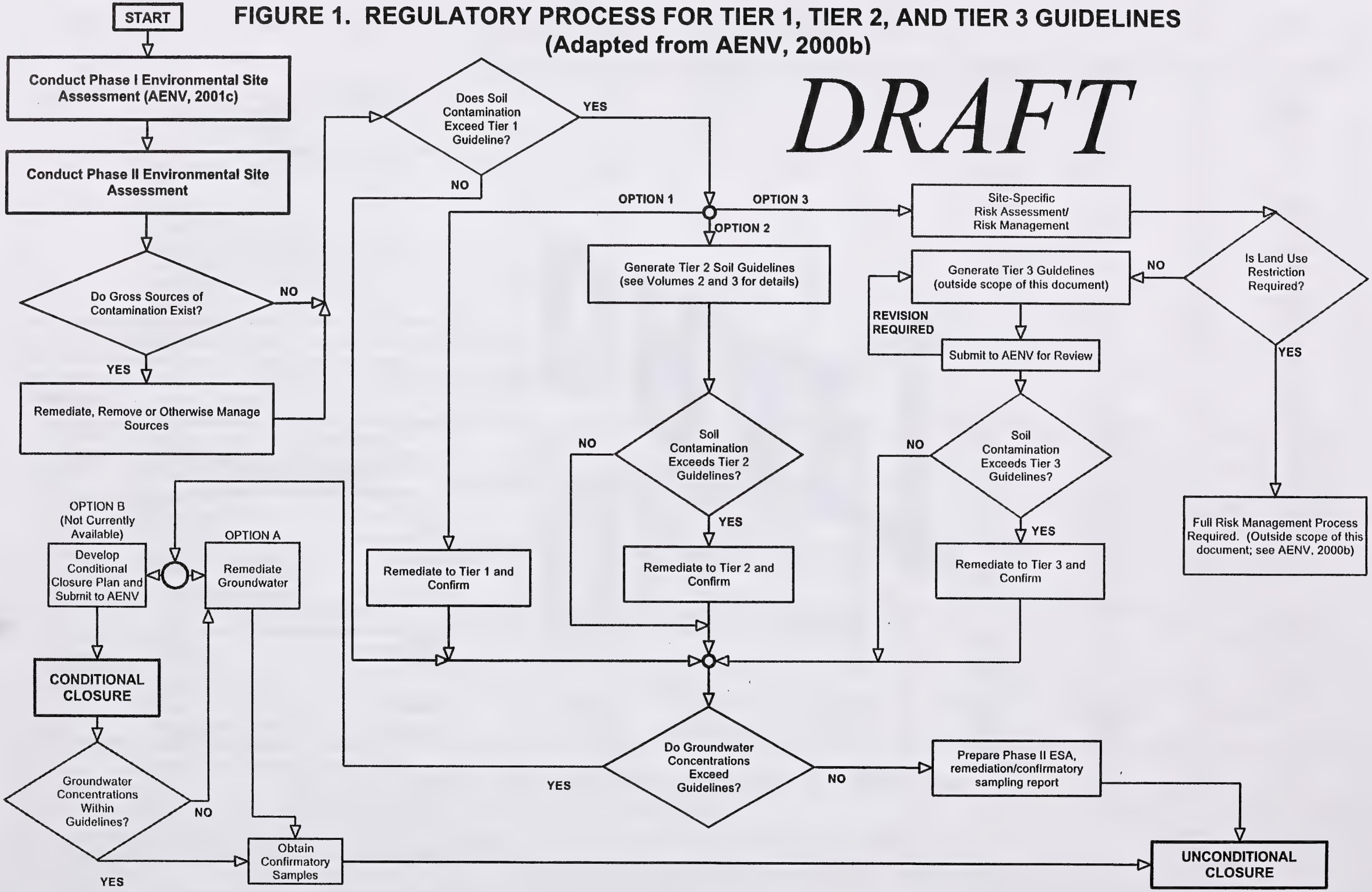
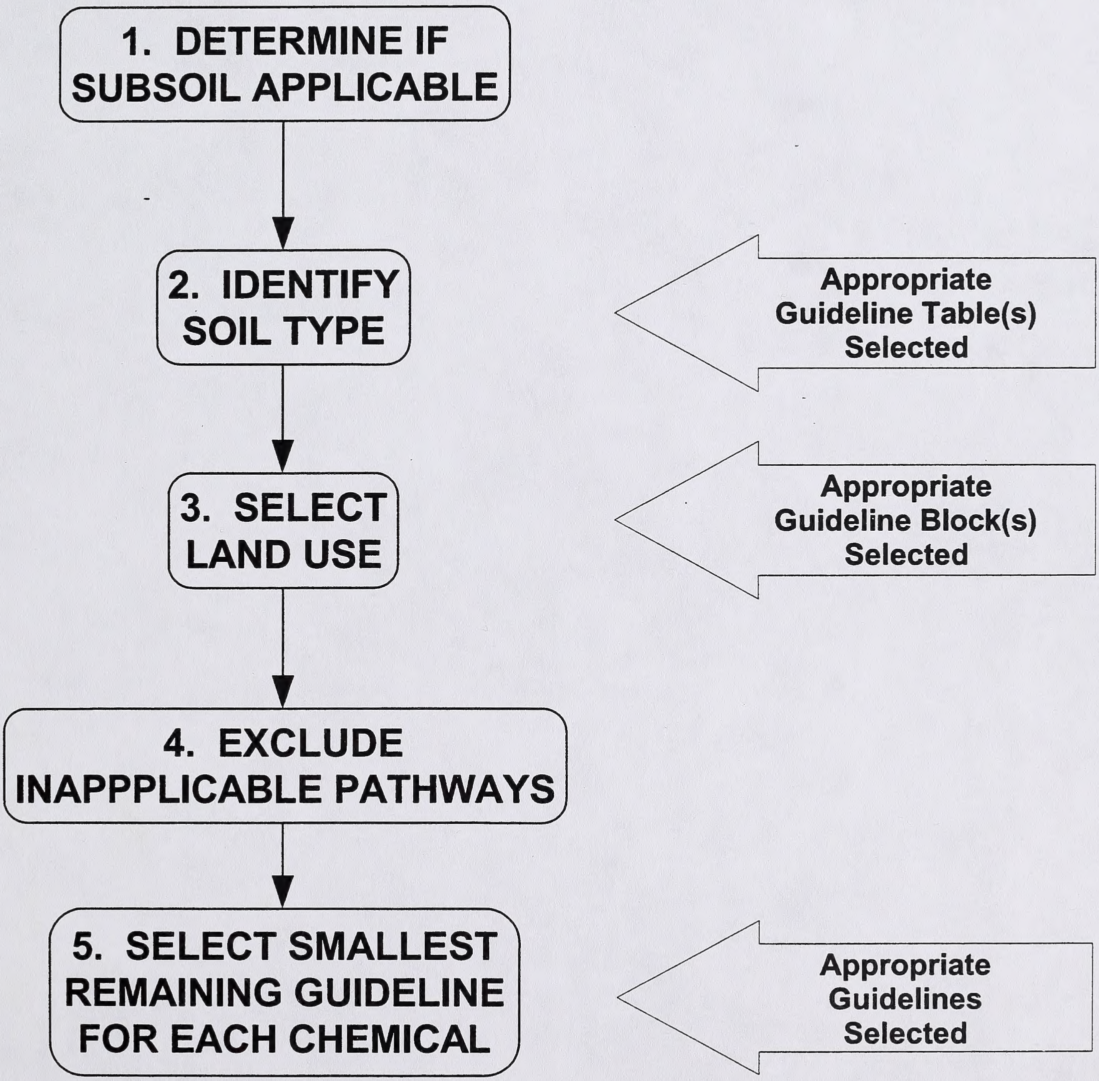

START
Conduct Phase I Environmental Site Assessment (AENV, 2001c)
Conduct Phase II Environmental Site Assessment
Do Gross Sources of Contamination Exist?
NO
YES
Remediate, Remove or Otherwise Manage Sources
Does Soil Contamination Exceed Tier 1 Guideline?
YES
NO
OPTION 1
OPTION 3
OPTION 2
Site-Specific Risk Assessment/ Risk Management
Is Land Use Restriction Required?
NO
YES
Generate Tier 3 Guidelines (outside scope of this document)
REVISION REQUIRED
Submit to AENV for Review
Full Risk Management Process Required. (Outside scope of this document; see AENV, 2000b)
Generate Tier 2 Soil Guidelines (see Volumes 2 and 3 for details)
Soil Contamination Exceeds Tier 2 Guidelines?
NO
YES
Remediate to Tier 2 and Confirm
Soil Contamination Exceeds Tier 3 Guidelines?
NO
YES
Remediate to Tier 3 and Confirm
Remediate to Tier 1 and Confirm
OPTION B (Not Currently Available)
Develop Conditional Closure Plan and Submit to AENV
OPTION A
Remediate Groundwater
CONDITIONAL CLOSURE
Groundwater Concentrations Within Guidelines?
NO
YES
Obtain Confirmatory Samples
Do Groundwater Concentrations Exceed Guidelines?
YES
NO
Prepare Phase II ESA, remediation/confirmatory sampling report
UNCONDITIONAL CLOSURE

FIGURE 2. DECISION TREE FOR TIER 1 SOIL GUIDELINE SELECTION

DRAFT


1. DETERMINE IF SUBSOIL APPLICABLE
2. IDENTIFY SOIL TYPE
Appropriate Guideline Table(s) Selected
3. SELECT LAND USE
Appropriate Guideline Block(s) Selected
4. EXCLUDE INAPPPLICABLE PATHWAYS
5. SELECT SMALLEST REMAINING GUIDELINE FOR EACH CHEMICAL
Appropriate Guidelines Selected